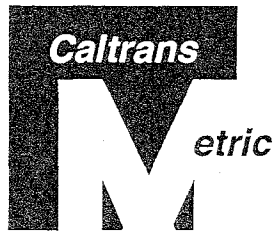


Caltrans Metric Conversion Plan



OCTOBER 1994



STATE OF CALIFORNIA
Department of Transportation
Division of State and Local Project Development
Office of Project Planning & Design

A word about metric conversion

The California Department of Transportation has an almost 100-year tradition of excellence and world leadership in transportation engineering. I am determined that the department shall maintain that tradition. Therefore, I am proud that Caltrans has chosen not just a pro-forma response to federal initiatives for metric conversion but instead is transforming itself into a metric organization. Our staff has undertaken the conversion with a positive attitude toward moving to a rational system of weights and measures.

Since August 1993, with a minimum of expense, Caltrans is well into an orderly conversion process. Interim metric design and drafting standards have been developed, metric survey and design are under way, computer systems have been converted and thousands of staff have been trained. All reports, plans, procurement and other internal processes will be expressed with metric units by mid-1996, whether subsidized by the federal government or not. Of the more than 1,600 projects currently under development, only a handful will be advertised for bid using English units after the mandated October 1996 conversion date.

Metric conversion is vital to our nation's health in a highly competitive economic world. Caltrans' leadership will help to shape a metric future for our country.

Sincerely,

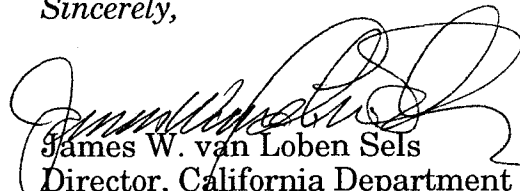

James W. van Loben Sels
Director, California Department
of Transportation

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I. Executive Summary

Introduction

The Caltrans metric conversion began on August 26, 1993, with the signing by Director James W. Van Loben Sels of Director's Policy Number 15, setting forth the Caltrans metrication policy, and the subsequent dissemination of Caltrans Deputy Directive Number 12, adopting the International System of Units as Caltrans' preferred system of weights and measures. These policies were established to comply with Federal law resulting from the Omnibus Trade and Competitiveness Act of 1988.

Organization

The Office of Project Planning and Design in the Division of State and Local Project Development was given the responsibility of managing the conversion, and two committees were formed. The Policy Committee is comprised of the Deputy Directors, District Directors from Districts 3 and 4, and the Assistant Division Administrator from the Federal Highway Administration. It provides policy guidance for major decisions. A Steering Committee made up of representatives of all Caltrans functional areas acts as a technical advisory team. Representatives of the Federal Highway Administration are also working members of the Steering Committee.

Policy Direction

The Policy Committee provided the following direction:

- Caltrans would meet the federal government's October 1, 1996 mandate for bid advertisement using metric units.
- Caltrans would employ the International System of Units (SI) as its single system of weights and measures to enhance efficiency and reduce confusion.
- Caltrans would not begin conversion of motorist information signs until this was to be done as part of a national effort.
- Hard Conversions would be done to the maximum extent possible without creating undue hardship on industry. (A "Hard Conversion" is a new rounded, rationalized metric number, whereas a "Soft Conversion" is an exact metric equivalent.)
- Dual units would be avoided wherever possible.
- Local agencies would be strongly encouraged to follow Caltrans' lead on projects not on the State Highway System, but funded with State or Local money. (Local Projects utilizing Federal funds are under the same Federal mandate.)

Progress

- Caltrans began a communication program with issuance of newsletters and other materials in October, 1993
- Caltrans has established metric mapping standards and began metric mapping in October 1993. The first metric maps were completed in January 1994.
- Caltrans issued interim design standards as scheduled in December, 1993.
- Caltrans began use of metric terms in reports as scheduled in January, 1994.
- Caltrans began metric design as scheduled in January, 1994.

- Metric Design and Drafting Standards and other policies and guidelines are currently under revision and expected to be published as scheduled in July 1995.
- Caltrans asked for and received exemptions for 70 projects on the State Highway System, and 34 City and County Federal Aid projects in April 1994.
- A four hour training class consisting of video and workbooks was developed and training classes began in January, 1994.
- A Metric "Primer" was established to disseminate conversion factors, rules and regulations for use of the SI units.
- Standard Plans and Specifications are currently being revised and are scheduled for completion in July 1995.
- Other functional units are converting their manuals and are expected to be released by July 1995.

Issues encountered to date:

- No additional personnel resources would be made available for the conversion.
- Metrication of the Post Mile System effects every aspect of record keeping in the Department and existing databases will require modification.
- Use of SI units would not be required for preparation of Transportation permits until there is a nationwide movement toward metric highway signing. Encroachment permits will be required to follow metric guidelines.
- SI units would be required for property acquisition records.
- Caltrans would pursue exemptions for a minimum of projects from the metric mandate.
- Locally financed projects on the State Highway System would be subject to the metric mandate.
- Caltrans would encourage local agencies to convert State-financed projects not on the State Highway System to SI units.
- The department will not initiate action to convert driver information signs to SI units except as part of a nationwide effort.

II. Introduction and History

A. Goals and Objectives

Caltrans set its metrication objectives in response to a federal mandate that all advertisements for construction projects or procurements using federal funds be expressed in metric units. However, the department has chosen to go beyond this mandate, setting out to become a fully metric organization internally, and in those external areas which do not directly affect the public.

The department will not initiate action to convert driver information signs to SI units except as part of a nationwide effort.

Metrication Goals:

1. Adopt the International System of Units (SI).
2. Satisfy the requirements of the Federal metrication mandate.
3. Complete a smooth and orderly transition to SI.
4. Accompany metric conversions by improvements in procedures and practices to minimize the cost.
5. Maximize the efficiency of Caltrans operations.
6. Refrain from any actions which inhibit conversion to SI, either within or outside of Caltrans.
7. Encourage early conversion to the metric system wherever possible.

Metrication Objectives:

1. Beginning January 1, 1994, use dual units (SI units should be the primary units followed by English units in parenthesis) in all technical reports which lead to a metric construction contract. Use SI only to express units of measure in these reports after January 1, 1995.
2. Use SI units of measure for all internal calculations after January 1, 1995.
3. Complete conversion of all standard plans, specifications, manuals, guidelines and policies by July 1, 1995.
4. Advertise for bid in SI units on all projects, regardless of fund source, after October 1, 1996 with the exception of 23 projects which had already been substantially under development by March, 1994 (70 projects have been granted exceptions from the metric mandate, 23 of them currently scheduled for advertisement after October 1996). The seismic retrofit program is scheduled to be substantially complete by October 1996, therefore the program manager has determined that the entire program will utilize English units. Some retrofit projects may require exceptions from the metric mandate.
5. Provide orientation and adequate training to all Caltrans staff required to use SI units prior to their initiation of such activities.

6. Conduct a program to notify and assist partners in the transportation community of the impending conversion.

B. History and Need for Conversion

Metric Conversion Act of 1975 and Omnibus Trade and Competitiveness Act of 1988

The Metric System is nothing new. It was first proposed more than 200 years ago, championed by Thomas Jefferson and Benjamin Franklin, and legalized in the U.S. in 1866. *The Metric Conversion Act of 1975* encouraged metrication, but left it as a voluntary activity. As a consequence, all efforts to convert were halted in the late 1970's when significant public outcry occurred. These efforts were not lost, however, since many of the standards that were developed in the 1970's are now being implemented.

The *Omnibus Trade and Competitiveness Act of 1988* amended the 1975 Act to designate the modern metric system (System International or SI) as the preferred system of weights and measures for U.S. trade and commerce. It also requires each Federal agency to convert to metric, and requires each Federal agency to use metric in its procurements, grants, and other business-related activities to the extent economically feasible.

These acts did not mandate that individual states, cities, counties, industries, or other organizations convert to metric. However, these entities cannot obtain Federal roadway money unless they use metric units. It is probable that all will convert to metric to remain eligible for road funds, and it is best that we all convert quickly using consensus guidelines.

Executive Order 12770

In addition to the congressional legislation, Executive Order 12770 was signed by President Bush in July 1991. It required each Federal agency to adopt a metric conversion plan by November 30, 1991. Among the other provisions of the executive order were instructions that the Department of Commerce was to lead the metrication effort.

The Federal Highway Administration Metric Transition Plan was approved by the Secretary of Transportation in October 1991. It laid out procedures and administrative policies for the conversion, and established certain milestone dates. For example, after September 30, 1992, FHWA publications and correspondence were to use metric as the primary system of units for all measurements. FHWA manuals and documents were to be systematically revised and republished in metric so they would be available to guide the conversion. The key date is September 30, 1996. All construction contracts advertised for bids after that date must contain only metric measurements for any Federal lands highway or Federal-aid highway construction project.

In August 1993, Director Van loben Sels directed Caltrans to convert. Since then, Caltrans has moved quickly. A metric conversion organization has been put in place

and the department has begun using SI units as the primary expression for internal reports. Interim standards for design and drafting have been adopted, and standard plans and specifications are in the process of conversion. Metric training has been provided to several thousand employees, and an extensive employee communications program has been undertaken. Caltrans staff members are now designing transportation projects using metric units, and the department expects to comply with the federal mandate.

Need for Conversion

There are only three nations that have not converted to metric: Myanmar (formerly Burma), Liberia, and the United States. Consequently, these three nations face serious difficulties in exchanging information with other nations, in conducting international trade, and in performing engineering or construction work with other countries.

The current global economy presents another serious difficulty. At the end of World War II, the United States was the center of world commerce. At that time America produced 75% of the world's products; today that value has shrunk to 25%. The world economy has changed rapidly, and industry in the United States is being placed at an increasing disadvantage because of its non-metric system of measurements. American firms are sometimes excluded from doing international business when unable to measure goods in metric terms. A few facts will help put this into perspective:

- The European Community (EC) is composed of 12 nations and is potentially the world's most powerful market, surpassing the United States. The EC specified that products with non-metric labels will not be permitted for sale after 1992.
- The largest U.S. trading partners, Canada and Mexico, are predominantly metric countries.
- Japan has identified the non-metric nature of U.S. products as a specific barrier to the importation of U.S. goods.

C. Benefits of Metric Conversion

International Acceptance

Metric is the world's measurement language. Fewer and fewer cultures are familiar with U.S. measurement units, and many are increasingly unwilling to overcome this hurdle in order to purchase and utilize American goods. The costs associated with doing business in this country (labor, taxes, tariffs, etc.) make it difficult for U.S. firms to produce their goods at prices which are attractive to other nations. They do not need the additional handicaps of non-standard sizes and a measurement system which is the exception rather than the rule.

International Competitiveness

Greater industrial efficiency and international competitiveness are available through the metric system. Canada has already converted to metric. The Canadian Metric Association reported that metric produced direct benefits in terms of reduction in

design costs and times, increased construction efficiencies, and improved material and component dimensioning techniques.

Private Sector Conversions Already Under way

Some U.S. businesses have already converted. One of the earliest industries to be affected by metrics was the automobile manufacturing sector. General Motors made an early decision that it must convert its manufacturing. Surprisingly, total conversion costs for GM were less than 1% of their original estimates. IBM and Otis Elevator are other examples of firms that have switched to metric, in this case to increase international competitiveness and to reduce their parts inventories. The wood industry has converted to metric for international sales. Timber products are being shipped overseas in metric sizes.

Opportunity to Consolidate or Redesign

The conversion process allows industries an opportunity to rethink their designs and to incorporate efficient practices. One way to do this is to designate fewer product sizes, reducing inventories and eliminating some manufacturing equipment. Rationalization of fastener sizes during metric conversion allowed IBM to reduce its number of fasteners from 30,000 to 4,000. The liquor industry reduced the number of container sizes from 53 to 7 during its metric conversion.

International Market for Engineering Services

Many American design and construction firms have already begun using metric units for their foreign work. Foreign billings for American architecture/engineering contracting firms amounted to \$3.2 billion in 1989, a substantial amount of business.

Simplicity

Perhaps the strongest argument in favor of the metric system is its simplicity of use. It is completely decimal based. There is no need to convert from one type of measurement to another type of measurement. For example, inches do not have to be converted to feet. Feet do not have to be converted to miles. Tablespoons do not have to be converted to cups. There is no requirement to change 27 feet, 8-1/4 inches into the equivalent number of yards.

The universal experience of every country that has converted has been that the metric system was easier to learn and easier to use than the convoluted system currently being used in the United States. It is just getting the transition under way that is hard. Once the mental leap has been made, calculations are much, much easier.

One Unit for Each Property

One of the greatest advantages is that there is only one unit for measuring each physical property. For example, pressure may be measured by psi, psf, kips/sf, inches of mercury or other units in the conventional U.S. system. The SI system has only one unit for pressure, the pascal. Another example involves power, which may be measured in hp, Btu's, watts, and several other terms. In SI, it is measured only in watts. Therefore, metric is a more coherent system in that only one unit is used for each physical quantity and there are no conversion factors to remember.

III. Departmental Approach

A. Organizational Structure

Responsibility for the conversion to SI has been placed with the department's Metric Coordinator in the Office of Project Planning and Design. No additional resources to date have been earmarked for the conversion. However, metric coordinators have been named for all Caltrans divisions and district offices (See Appendix A1). Metric coordinators serve on the Metric Steering Committee. Their duties are described below.

Two metric committees are responsible for activities associated with the metric conversion:

The Metric Policy Committee provides general policy guidance for the conversion and:

- Recommends approval of the Caltrans Metric Conversion Plan to the Director
- Uses broad decision-making powers to implement the Metrication Policy
- Works with the Governor's office, the legislature and others to effect changes in laws to incorporate metric standards.
- Coordinates with other State agencies, local agencies and others to ensure a smooth metric conversion.
- Works with and oversees the efforts of the Metric Steering Committee

The Metric Steering Committee:

- Forms technical advisory teams to perform specific tasks
- Identifies activities and programs to be converted
- Formulates the metric conversion plan and specifies timetables and resources for completion
- Assigns conversion responsibilities to appropriate functional units
- Establishes metric standards
- Plans and conducts public awareness program, in coordination with the Office of Public Affairs
- Develops training and orientation classes for Caltrans employees
- Oversees implementation of the metric conversion

The Communications Subcommittee:

- Identifies those, both inside and outside of Caltrans, likely to be affected by Caltrans' conversion to the metric system
- Determines the most effective means of communicating with them
- Approves individual communications elements

The Training Subcommittee:

- Sets training goals and objectives
- Assesses processes which must be converted for training implications
- Estimates the number of employees who must be trained
- Approves the Metric Training Plan
- Develops and approves individual training instruments
- Monitors and Evaluates progress in meeting training objectives

B. Coordination

Caltrans has worked closely with FHWA and the American Association of State Highway Transportation Officials (AASHTO) and has been in touch with a number of other states and local agencies with regard to metric conversion. The Department has established a statewide Metric Coordinator within the Office of Project Planning and Design to direct the conversion process and provide assistance to Districts, Divisions, local agencies, consultants, contractors, industry, and the general public. The Metric Coordinator has exchanged information and contributed to national uniformity by attending a number of nationwide and regional conferences on metrication and continues to coordinate with other state DOT's. The Metric Coordinator also acts as liaison between the Policy Committee, Steering Committee, and other elements of Caltrans headquarters management.

Caltrans has established Metric Coordinators for each District and Headquarters Division. The Metric Coordinators:

- Serve on the Steering Committee (3 Districts are represented)
- Direct the metric conversion within their Division or District
- Provide information to the Policy and Steering Committees regarding all phases of the conversion within their Division or District
- Serve on appropriate subcommittees
- Set up and coordinate training sessions within their Division or District
- Coordinate communications regarding metric conversion within their Division or District
- Provide liaison with outside agencies, consultants, contractors and the general public in their geographic area.

C. Division and District Summaries

Following is a summary, by organization of Caltrans' metrication activities, issues, and estimated costs. The estimated costs provided in this section and summarized in Appendix 2 were gathered from a survey of the Districts and Divisions. Many of the costs are difficult to separate from other normally scheduled activities. Therefore the accuracy of these estimates may never be verified. ***This section was written based on the old Caltrans organization structure. The Department is currently reorganizing. At the time of this publication, many decisions have not been made. Therefore this section was not rewritten around the Transformed Caltrans. Where possible the new Division titles have been provided in italics to assist the reader. Since there are no additional PY's or dollars budgeted for metrication (all costs shown in this plan are to be absorbed through reallocation of existing resources), there was no attempt to separate portions of the original estimate to fit this new organizational structure.***

Caltrans Districts

General:

In general, the Caltrans Districts have responded positively to the metrication effort. The greatest impacts tend to be the slightly increased workload in project

development during the conversion period. Estimates of the additional time and effort for metric design range from about 0.5% to 10% (this range was received from the District surveys) during the transition period. District staffs are receiving training in the metric system as scheduled, and it does not appear that there will be any special difficulty in getting staffs oriented to the system. In addition, large numbers of staff have already been educated in the metric system, either because they were educated in foreign countries, or because they received college training in it. There is considerable enthusiasm for the change in District offices.

Issues:

Metrickation issues are covered in sections below pertaining to functional areas.

Procedures/Manuals to be Converted:

No additional procedures or manuals were named as requiring conversion other than those covered in sections below pertaining to functional areas.

Estimated Cost:

\$765,000
88 personnel years

Division of Aeronautics

General:

The Division of Aeronautics does not anticipate difficulty in meeting the federal metrickation mandate. General aviation airport construction is funded by general aviation fuel taxes, and projects are usually constructed to FAA standards. Project sponsors use current Caltrans standard plans and specifications, or standard plans and specifications for public works construction related to their area of work. In those cases, the Division assures that they are comparable with State and FAA standards. Most contractors performing work on airport projects are involved in roadway construction with Caltrans and local agencies. Because they are likely to be working with metric highway plans, they should not encounter significant difficulty.

Issues:

Worldwide aviation operations have adopted US units as a worldwide standard and are not expected to change. However, SI units will be used for the construction of airport facilities.

Procedures/Manuals to be Converted:

None

Estimated Cost:

\$3,000
0.1 personnel years

Division of Construction *(the Office of Office Engineer is now a part of the Engineering Service Center)*

General:

Conversion activities in the Division of Construction are among the most extensive within the Department, and are crucial to completion of the conversion by October, 1996. Among the most important items are conversion of Standard Plans and Specifications and several manuals providing guidance for drafting and construction activities.

Issues:

Conversion of standard plans and specifications, to be completed by July, 1995, is being undertaken as part of a larger replacement of standard plans and specifications on CADD. Plans and specifications are revised by staff in the Office of Project Planning and Design, Structures, Landscape Architecture, Traffic and other functional units. The Office Engineer then incorporates them into published final sets. The conversion schedule thus depends on the ability of those functional units to provide Office Engineer with revisions on time. There is concern that diversion of resources to the Seismic Retrofit program, particularly in the Division of Structures, may result in delay of the revisions.

In many cases, local agency standard plans and specifications are incorporated into the contract plans and specifications. Unless the local agencies are on schedule with conversion, there may be some jobs for which there may be both metric and US plans.

Procedures/Manuals to be converted:

PS&E Guide
Drafting and Plans Manual
Project Plan Preparation Manual of Instructions
Basic Engineering Estimating System
Construction Manual
Highway Construction Checklist Pamphlet
Construction Engineer and Management Forms

Estimated Cost:

\$701,000
23 personnel years

Division of Engineering Management *(This Division is renamed the Division of Program Management; the Office of Central Design now resides in District 3; the Offices of Geometronics and CADD are a part of the Engineering Service Center)*

General:

Activities within the purview of the Engineering Management Division are crucial to Caltrans' metric conversion, particularly the CADD symbology library and the Project Management Control System. Mapping and Surveys must be converted in order for all other engineering activities to follow.

The Geometronics branch has developed metric mapping standards and has worked with Materiel Operations to establish an inventory of metric measuring tools. The photogrammetry section issued contracts for fiscal year 94/95 which include new metric specifications. The photogrammetry section has converted its CADD symbology libraries and other computer programs and files used for photogrammetric work. The Surveys section has converted the software and the manuals used with the Total Station Survey System and is working on the Caltrans Surveys Manual.

The Engineering Technology Development Branch has responsibility for maintaining the Caltrans CADD system software. The RDS system has been converted and all other software, software manuals and software training materials are being converted to the metric system on schedule.

Issues:

Land surveying measurements must be converted using the special conversion factor for the US Survey foot, rather than the standard survey foot. The Geometronics Branch is advising all users of survey data about this special conversion factor.

Procedures/Manuals to be Converted:

Caltrans Surveys Manual
Correlation Plotting Manual
Photogrammetry Specifications and Mapping Standards
Data Collection Software and Manuals for the Total Station Surveys System
Land Surveys For Rights of Way Syllabus
RDS Manual

Estimated Cost:

\$135,000

18 personnel years

Environmental Division

General:

The Environmental Division issued a memorandum December 29, 1993, stating that metric units would be used in all reports issued after January 1, 1994, except for technical cultural reports, resource-related information, maps as reflected in the historical record and as required by professional standards. All environmental personnel were instructed to portray a positive aspect when dealing with the public regarding the conversion.

Issues:

SI measurements were introduced in environmental documents in January 1994. No difficulties have occurred to date with public perceptions.

Procedures/Manuals to be Converted:

Environmental Handbook, Vol. I and II. (relatively few dimensions in either)

Estimated Cost:

\$1,000

No personnel years

Division of Highways *(now the Division of Highway Systems Information)*

General:

The Division of Highways does not anticipate any major problems with metric conversion. Several reporting systems maintained by the Division of Highways rely on data from systems such as the Highway Inventory and TASAS, which are maintained by other units. Changes in these systems will result in minor workload impact.

Procedures/Manuals to be Converted:

None

Estimated Cost:

\$7,000

3.5 personnel years

Division of Information Services

General:

The Division of Information Services began converting 23 statewide information systems to metric on April 1, 1994, with completion expected by September, 1996. The conversion for most systems will involve changing program code to replace US units with metric units. Only three of the systems, Speed Monitoring, Truck ADT Master and Traffic Volumes, involve conversion of history files. No major problems are anticipated.

Procedures/Manuals to be Converted:

None

Estimated Cost:

\$1,000

7 personnel years

Legal Division

General:

The Legal Division, in cooperation with Legislative Affairs, will have the role of preparing for the transition of Laws and regulations based on U.S. measurements to metric, and assisting in the adoption of regulations in cooperation with affected units.

Procedures/Manuals to be Converted:

None

Estimated Cost:

0.2 personnel year

Division of Maintenance

General:

The primary impact of metrication on maintenance is in the areas of record-keeping, inventory, and measurement of materials. While maintenance activities are not critical to other metric conversion steps, there is a potential for cost and some confusion as the conversion goes forward. However, there are some opportunities for simplification of some processes.

Issues:

The Division of Maintenance tracks 118 items in its physical inventory based on the current postmile system. Annual changes in the inventory form a basis for resource and funding requests. Conversion to metric units will thus require a new method of tracking the inventory. This may present an opportunity to dramatically reduce the number of items being tracked.

The Maintenance Management System, also tied to the current postmile system, counts materials, chemical measures and production units in US units. These will have to be converted.

If driver information signs are ultimately converted, this will have an enormous impact on the workload of maintenance.

Procedures/Manuals to be Converted:

Maintenance Inventory System
Maintenance Management System
Maintenance Manual Volumes I and II

Estimated Cost:

\$103,000
3.5 personnel years

Mass Transportation (Includes Rail)

General:

No problems are anticipated with the metric conversion. Railroads are regulated by the Federal Railway Administration, which is developing a conversion plan of its own; no information is available on the plan at this time. Metric conversion is not expected to have a major impact on other transit-related activities.

Issues:

Many improvement projects administered by the Division of Rail are for projects on private property owned by railroads, which are not likely to convert anytime soon. There will be no attempt to require the railroads to adopt SI units.

Procedures/Manuals to be Converted:

None

Estimated Cost:

\$1,000

0.2 personnel years

Division of New Technology, Materials and Research *(now the Division of New Technology and Research; the Transportation Laboratory is now a part of the Engineering Service Center, split into the Office of Structural Foundations and the Office of Materials Engineering and Testing Services)*

General:

The Division of New Technology, Materials and Research is among the leaders of the conversion effort at Caltrans, and is taking the opportunity during metric conversion to examine opportunities to bring Caltrans testing procedures into conformance with AASHTO and other standardized testing procedures. The division is also examining opportunities to effect efficiencies by simplifying engineering measurements and calculations. Additionally, because the division's workload is highly technical in nature and is often grounded in basic research, use of the metric system will allow the division to participate more actively in useful research from other disciplines. Although some cost is expected to be incurred as a result of conversion, the division expects these costs to be offset over a period of time by improved procedural and labor efficiencies

Issues:

None identified.

Procedures/Manuals to be converted:

Materials and Testing Manuals

Flexible Pavement Rehabilitation and Structural Section Design Guide

Water Manual and Coastal Salt Marsh Guide

Air Quality Manual

Noise Manual

Estimated Cost:

\$560,000

6.5 personnel years

Division of State and Local Project Development *(now the Division of Design)*

General:

The Division of State and Local Project Development is responsible for the metric conversion, through the Office of Project Planning and Design. The Office of Project Planning and Design and the Office of Landscape Architecture are responsible for revision of several standard plans and specifications. The Office of Local Programs is responsible for liaison with local agencies.

To date, OPPD has produced interim design standards and drafting standards, the metric primer, and the 4-hour metric training class. OPPD is currently converting the Highway Design Manual. The new Project Development Procedures Manual, expected to be published in late 1994, has incorporated metric units.

Issues:

The workload occasioned by the metric conversion has been placed on the Office of Project Planning and Design without a concomitant allocation of resources.

There are varying degrees of enthusiasm for the metric conversion among the local agencies, ranging from the City of Los Angeles, which is aggressively implementing the metric system, to many cities and counties which appear to simply hope that the conversion is postponed again. Caltrans is using various strategies to communicate with the local agencies, including regular channels through the Office of Local Programs, the Metric newsletter (effective September 1994, the newsletter has been canceled and will be replaced by the issuance of Departmental memorandums as needed), frequent presentations at meetings sponsored by local agencies, the active participation of local agency representatives on the Steering Committee, and the Cooperative Training and Assistance Program at the Institute of Transportation Studies at U.C. Berkeley.

Procedures/Manuals to be Converted:

Highway Design Manual
Project Development Procedures Manual
Special Funded Programs Procedures Manual
High and Low Risk Utility Policy Guidelines

Estimated Cost:

\$252,000
6 personnel years

Division of Right of Way

General:

Metriation in the Division of Right of Way presents some interesting and unique challenges. The majority of the Division's property acquisition and disposal efforts depend upon and require the cooperation of individuals, institutions and business entities which are not governed by the FHWA or any existing State rules or regulations regarding the use of metric units. However, the Division is proceeding

on the basis that it will in-fact be able to conduct the majority of its business using metric units only. Exceptions will be made, in limited fashion, for those situations that demand the use of dual units to avoid project delays. In an effort to establish understanding and acceptance of the metric system, the Division will be doing its best to inform and educate those members of the public and private sectors with whom we must carry on business dealings.

Issues:

The actual degree of cooperation received or the additional time required to get full cooperation from the property owners, title companies and mortgage bankers on transactions of varying complexity is difficult to gauge at this time. It is possible that our efforts at persuasion will be too time consuming in which event we would be obligated to retreat to the use of dual units (also a time consuming and inefficient activity).

There was initial concern about the recording of property conveyance documents with County Recorders. However, both Imperial and metric units are legal in California and it appears that recordation will not present a problem.

There is uncertainty regarding the amount of additional effort that may be entailed in the course of preparing for Eminent Domain proceedings where Imperial-only or dual units may be required.

Procedures/Manuals to be Converted:

Right of Way Procedures Manual

Right of Way Engineering Chapter of the Drafting and Plans Manual

Estimated Cost:

\$93,000

7.5 personnel years

Division of Structures *(now a part of the Engineering Service Center)*

General:

The Division of Structures has responded positively to metrication. However, it is responsible for a very large project development program which will be heavily impacted by metrication. The division is already under great pressure to accelerate the Seismic Retrofit program, and is concerned that it may be unable to meet the metric mandate and implement that program as well. Other impacts include training of staff, the revision and redesign of standard plans, and the revision of specifications.

Issues:

The division estimates that metrication, over a two year period, will require twenty one additional personnel years (the actual cost is estimated at 48.5 PY's, but the division will redirect resources to cover the balance). Unless these resources are provided the Division will be unable to meet the demands on it.

Procedures/Manuals to be Converted:

Bridge Design Aids
Bridge Design Details
Bridge Design Practice
Bridge Design Specifications
Construction Manuals
Anvil Drafting Manual
Bridge Local Programs Manual
Handbooks
Structures Design Standards

Estimated Cost:

\$359,000
52 personnel years

Division of Traffic Operations

General:

Metrickation in the Division of Traffic Operations is crucial to the larger metrickation effort. The division is responsible for maintenance of the current post-mile system, around which all statistics about the State Highway Program are organized.

The division is also responsible for encroachment and oversize load permits, both of which must be prepared by non-Caltrans individuals. **See section entitled "Conversion of Transportation and Encroachment Permits"**

Issues:

The guidelines for the new kilometer based reference system have been established and the Highway Data Base will be converted by June 30, 1995. **See section entitled "Conversion of the Postmile System"** The Division of Traffic Operations will need to acquire new photologging equipment that will record direct to disc and will have the option of frame spacing in mile or kilometer fractions.

The Division will also be heavily impacted by any metric sign conversion effort, if a nationwide policy to implement occurs. In the interim, signs will be designed, sized and located in metric terms, but the message will remain in Imperial units. **See section entitled "Metric Sign Conversion"**

Procedures/Manuals to be Converted:

Traffic Manual
Signal and Lighting Design Guide
Ramp Meter Design Guidelines
Changeable Message Sign Guidelines
Transportation Permit Manual
Encroachment Permit Manual

HOV Guidelines
Park and Ride Guidelines
Truck Network Maps
Size and Weight Limits In California

Estimated Cost:

\$221,000
14 personnel years

Division of Transportation Planning *(now the Division of Planning)*

General:

The Division of Transportation Planning has indicated that metric conversion will not be a major impact to them. The only anticipated change is the use of SI units in reports, for which conversions are relatively simple. Some reports are distributed to the general public, and may require interpretation by them, but this is not anticipated to be a problem.

Issues:

None

Procedures/Manuals to be Converted:

None

Estimated Cost:

\$38,000
0.5 personnel years

IV. Laws and Regulations

Preliminary analysis indicates that as many as half of California laws and regulations, primarily in the Vehicle Code and the Government Code, contain references which use US measurements. These laws and regulations also govern the actions of a number of other agencies, particularly the California Highway Patrol and the Department of Motor Vehicles, but they also impact other agencies with public works programs such as Corrections, Water Resources, and the Department of the State Architect. To change the regulations in the short range as part of a specific legislative act would be a monumental task, possibly unpalatable to members of the California Legislature and to the other agencies involved.

It has also been determined that these laws and regulations do not require change until such time as the nationwide signing effort is implemented. Therefore at this time the Department will not propose metric related legislative change. If metric signing is adopted in the future the recommended approach to these changes would be as follows:

First, to develop interagency communications to determine those actions which can be taken cooperatively and without legislative action. To this end, Caltrans has made contact with other agencies having public works programs or who are affected either by the federal mandate or by anticipated changes to laws, codes or regulations, and is developing a liaison mechanism to assure that such changes do not have a detrimental effect.

Second, after consultation with other affected agencies, Caltrans will propose legislation requesting general authority to change the unit expressions through regulatory action, working in concert with the other agencies affected and with the California Office of Administrative Law.

V. Adopted Standards

A. Metric Units, Terms, Symbols and Conversion Factors

In concert with FHWA and other federal agencies, Caltrans has adopted ASTM 380, *Standard Practice for the use of the International System of Units (SI) (The Modernized Metric System)* issued by the American Society for Testing and Materials, as the standard of metric expression for its engineering and other internal processes with only one exception: to use the American spelling of "liter" and "meter", rather than the European spelling (litre and metre). ASTM 380 is updated annually, and Caltrans will use updated versions of the standard.

Caltrans has excerpted materials from ASTM 380 which are pertinent to its processes, and assembled them in a booklet entitled *The Metric Primer*. Thirty thousand copies of the primer have been printed; they have been distributed to all Caltrans staff, local agencies, consultants and construction firms. A facsimile of the primer is included as Appendix A3 of this plan.

This Plan will not include specific design criteria, standards or procedures. These will be distributed as interim memorandums as they are established and will be replaced with the distribution of all manuals, standard plans and specifications by July 1995.

Substitute Symbols

Certain computer programs or other data processing devices do not allow for the use of superscripts and other Standard nomenclature. Caltrans has adopted the following substitutions for these instances. These were taken from the International Standard Organization (ISO) publication ISO-2995-1974 and are recognized as International standards.

UNIT OF MEASURE

ASTM E380 Symbol	Caltrans Substitute	Unit
m	M	meter
m ²	M2	square meter
m ³	M3	cubic meter
km	KM	kilometer
kg	KG	kilogram
ha	HA	hectare
h	H	hour

These should only be used where the proper lower case script and superscripts are not available.

Pay Item Convention

The Basic Engineering Estimating System (BEES) has field limitations and will not accept superscripts or subscripts. The following has been established to address these limitations. However, the standard nomenclature should be used in all other applications including the specifications.

<u>Existing Unit</u>	<u>Metric Symbol</u>	<u>Unit</u>
LF	M	meter
SQFT	M2	square meter
EA	EA	each
SQYD	M2	square meter
CY	M3	cubic meter
LNMI	LNKM	lane kilometer
TON	TONN	tonne (1000 kg)
CF	M3	cubic meters
LS	LS	lump sum
ACRE	HA	hectare
STA	STA	station (100 m)
MI	KM	kilometers
LB(S)	KG	kilograms
TAB	TAB	tablet
GAL	L	liters
MFBM	MFBM	thousand foot board measure
HR	H	hours

B. Paper Sizes

The Department will adopt the ISO "A" series of paper sizes, however **we will continue to use English sized paper until the paper manufactures begin producing the metric paper.**

The ISO "A" series sizes are the preferred international paper sizes. There are five "A" series sizes:

A0	1189 x 841 mm (46.8 x 33.1 inches)
A1	841 x 594 mm (33.1 x 23.4 inches)
A2	594 x 420 mm (23.4 x 16.5 inches)
A3	420 x 297 mm (16.5 x 11.7 inches)
A4	297 x 210 mm (11.7 x 8.3 inches)

A0 is the base drawing size with an area of one square meter. Smaller sizes are obtained by halving the long dimension of the previous size. All A0 sizes have a height to width ratio of one to the square root of 2.

Caltrans will continue to use the established 22" x 34" trim line dimensions printed on 24" x 36" paper. The established image areas will remain the same until the Department switches to the "A" series paper. At that time the image area will be adjusted to fit the new paper. There will no longer be a need to have trim line dimensions to obtain a full 50 % reduction.

C. Conversion of the Postmile System

The postmile system is a vital link to the department's ability to reference and relate all historical data, current project data, maintenance inventory and accident data to specific highway segments. It also serves the general public to a limited extent for highway travel and location. The intention of FHWA is to enhance the general public use by providing continuous postmile markers and freeway exit numbers.

The source of postmile data which all of the department's systems interface with for consistency is the TASAS Highway Data Base. This database contains historical descriptions of approximately 20 000 intersections, 13 000 ramps, and 24 500 km (15 200 miles) of highway segments. Other databases which interface with TASAS may utilize all or portions of the TASAS Highway Data Base. Making significant changes to TASAS would cause the systems to be incompatible.

The Department is currently developing a corporate database which eventually would replace the existing outdated systems. This new corporate database can be designed to accommodate the department's needs for a metric based data system. See **section entitled "Conversion of Corporate Database"**

The following guidelines have been adopted for the conversion of the postmile system in TASAS and for all other postmile applications.

1. The postmile system shall be soft converted from miles to kilometers using the factor of 1.6093. All postmile values in the Highway Data Base will be converted to kilometers using this factor.
2. The lateral dimensions (shoulder, traveled way, and median widths) will not be converted at this time since the database fields cannot accommodate the converted values.
3. The existing postmile prefixes and suffixes and all equations (including equations at county boundaries) will be retained.
4. All projects leading to a metric construction contract can utilize the converted postmiles now and shall designate them as "KP" (kilometer posts) on all appropriate documents.
5. The TASAS Highway Data Base will be converted after the 1994 year end summaries have been published and no later than June 30, 1995.
6. Databases shall store one reference system or the other. Comparison between reference systems can be done with a simple mathematical calculation.
7. Postmile paddles shall not be changed in the field since it is a simple mathematical conversion and the department anticipates a different future GIS based reference system.
8. The exit numbering signs are independent from the reference system and may be implemented as part of an overall metric sign conversion effort or earlier if necessary.

VI. Computer Applications

A. Metric CADD Implementation

The Headquarters Office of Engineering Technology (OET) has begun the conversion of CADD software and manuals. The metric design standards will be incorporated into the CADD updates as they become available.

There is no automated method for conversion from the existing U.S. System units to Metric units for existing design files. For this reason we encourage all Project Engineers to take a second look at their target PS&E Submittal dates. In some cases it may make good sense to convert recently-started projects to the metric format in case the PS&E submittal date slips.

Status of CADD Software Metrication

- **IGrds - Interactive Graphics Roadway Design System IGrds AN & IG:** In February 1994, OET released a software patch for IG92 which provides district designers with configuration files and information needed to produce metric highway designs. As many issues as possible were identified at that time. As additional issues surface they will be resolved while working closely with district staff.

Currently the IG93 release of IGrds is undergoing testing with an expected distribution date of Fall 1994. This full metric version will only work on the new HP workstations. The old workstations will continue to use IG92 with the metric patch.

- **ADVOCATE:** Except for some dimensioning commands and the plot request, Advocate is unitless dealing only in graphic units. These two areas have been enhanced to accommodate either the U.S. or Metric system, depending on which mode it is in.
- **RDS PANELS:** The RDS Panels is the front-end software to IGrds AN that provides the user with "fill in the blank" forms for creating input data. The February 1994 patch contained metric as well as U.S. panels.
- **CAiCE - Digital Terrain Model:** CAiCE is Digital Terrain Modeling and Coordinate Geometry software. This software has always had metric capability and no enhancements are necessary.
- **MTCEL940 - Caltrans Metric Symbol Library:** The February 1994 patch from OET included a metric version of CTCELLIB which will contain approximately 600 cells. The remaining 500 cells will be available with the IG93 release.
- **ROARS - Roadway Overlay And Rehabilitation System:** This software will not be metricated. ROARS functionality is now provided by features of CAiCE released in the Spring of 1994. Some training of District staff will be required and development of a course is underway.
- **TERLI - TERRain Line Interpolation:** Terli is used to generate terrain data for IGrds AN from TLI survey data. This software is unitless. The output is in the same units as the input data. There are several computer programs developed by district personnel that will convert a TLI points file from feet to meters. We will release one of these programs as part of the IG93 release.

- **DRAIN:** The DRAIN program runs in conjunction with IGrds. Its purpose is to define, display, modify, label and tabulate drainage systems. Enhancements are currently underway to provide metric capability for this program and it will be distributed to the districts with the IG93 release.

Other Engineering Software

We are currently working on software which will generate metric RD05 and RD10 input data for IGrds AN software from IGrds AN reports in feet. We expect to release this software with the IG93 release.

OET will not modify CADD software residing on the IBM Timeshare system. This includes HIDES, AGENT, PROFILE, ROARS, RDS, SURVSY, TACO, TRAV, VMTRAV and any other programs that use the Engineering Database. These applications are all obsolete and have been replaced by software available on workstations.

Drafting System

The drafting system currently has the capability of producing plans in either U.S. system or Metric system units.

CADD Training

Metric standards will be incorporated into CADD training material as the courses are rewritten for the new HP workstations.

If you have any questions regarding CADD applications, please call Doug Printz, CADD Metric Coordinator at (916)-654-5258 or Calnet 464-5258.

B. Conversion of the Corporate Database

The Department is currently developing a corporate database which will eventually replace and enhance all existing databases utilized by the Department. The Metric Coordinator has met with and reached agreement with the corporate database team on the following issues.

1. The corporate database will be designed utilizing metric units only, even though some early trial efforts are underway to download existing data from other systems in English units.
2. Existing data will be downloaded and soft converted prior to storing in the corporate database. The size of each field shall be determined by the precision required for the most precise application, as determined by the users. Reports developed from the database can generate lower precision outputs at the discretion of the users.
3. The corporate database will be designed to accommodate the new "KP" reference system as discussed in the section entitled "Conversion of the Postmile System". It will also be designed to accommodate a continuous kilometer reference system from origin of route to terminus of route and a future GIS reference system.
4. The corporate database shall run in parallel to existing systems until such time as it can replace them. This may require some extensive programming to duplicate or replace existing analysis applications.

VII. Impacts Outside the Department

A. Impacts to Local Agencies

Local agencies using any federal funds fall under the same metric mandate as Caltrans. In addition, Caltrans will require that any local agency doing a project on a State Highway prepare plans in SI units. Finally, Caltrans is encouraging local agencies to use SI units when preparing any plan, because of the need for uniformity throughout the construction industry and because most projects use both local and state plans.

Caltrans has worked closely with representatives of local agencies on the conversion. Representatives of the League of California Cities, County Supervisor's Association of California and the locally financed transportation authorities have served as members of the Steering Committee. The Caltrans Metric Letter has been distributed regularly to cities, counties, and regional agencies. Training materials have been made available through the Cooperative Training and Assistance Program. Several presentations have been made to various associations and meetings of local agencies. In addition, the Caltrans Office of Local Programs has maintained regular liaison with the local agencies.

There are varying degrees of enthusiasm for the metric conversion among the local agencies, ranging from the City of Los Angeles, which appears to be making a major effort, to many cities and counties which appear to simply hope that the conversion is postponed again.

Issues

The concerns of local agencies mirror those of Caltrans itself. Because no additional funds have been made available from either state or federal sources, the already-strapped local agencies must reallocate scarce existing resources to the conversion.

The greatest local agency concern is about possible conversion of driver information signs. Any change of the signs, they say, could only be done if additional state or federal money were made available to them.

As with the State of California, many codes and regulations will have to be changed. For the local agencies, becoming fully metric also means that local developers will have to begin submitting building plans using SI units, something that is likely to have a very large impact on the public and public opinion.

The local agencies do not anticipate a great deal of difficulty with their own staffs, many of whom, as with Caltrans, are already partially conversant with the metric system.

B. Impacts on Industry

Caltrans has included representatives of the transportation construction industry on the Steering Committee, and has worked with them in communicating with the industry. As conversion nears, the department will work with the industry to provide training and communication materials.

Metric conversion is expected to impact construction contractors. Most of those in construction have spent their lives thinking in US quantities, and as the transition occurs may have some difficulty in dealing with metric quantities. This may result in inefficiencies and possibly delay. Following are specific contractor concerns:

Estimating

Because significant effort will have to be expended in converting historical data used by contractors in bid preparation, Caltrans may experience increases in requests for relief of bid early in the process, and requests for subcontractor substitution. Both these items are addressed in statute and should be studied closely in case change is necessary. Errors discovered during construction may appear as additional disputes and claims.

Purchasing

Because Caltrans will do both soft and hard conversions, material purchasing will be impacted, particularly in rural areas. The industry is concerned that there may be difficulty finding hard-converted items and suggests that Caltrans provide a listing of hard converted items with each bid.

Scheduling

Contractors may have difficulty in schedule preparation because historical data on production is currently stored in US units. Current policies on schedule preparation and presentation should be reviewed.

Quantity Disputes

Disputes over quantities may be expected where conversions are required. The issue of final pay quantities may offer special problems with respect to probable errors in estimating.

Conversion Costs

There may be significant costs to industry in accomplishing the conversion. Costs of tools and equipment required to produce metric products will depend on what is subject to "hard" or "soft" conversion. Certain products will be easily converted to new "hard" standards, others will not. Where industry is not able to retool at this time, the new standard should be established, but with increased tolerances to allow the existing products to be relabeled and supplied. This will guide industry to the appropriate standards when retooling is necessary, without forcing them to retool earlier.

Additional costs may be attributed to conversion of historical bidding data and employee training. It is important to note that these are overhead costs, not easily applicable to bid items.

Subcontractor Issues

The impacts of conversion may be felt hardest by small unsophisticated subcontractors, resulting in additional disagreements between prime and subcontractors. Those firms certified as minority or disadvantaged have access to a supportive service contractor. Special efforts should be made to assure that these service contractors provide information on metric conversion to DBE firms.

C. Metric Sign Conversion

The conversion of highway speed limit and information signs is a separate and independent issue from the ongoing internal metric conversion. The Department will not consider converting signs until such time as a nationwide signing policy is established and Congress supports it.

Current law prohibits use of federal funds for conversion of driver information signs. If there is a nationwide move to metricate the signs, money (the estimated cost of converting Highway signs on the State Highway System is approximately \$20 million) will have to be made available. Prior to implementation of such a policy, a broad-scale public information campaign would be required to alleviate the anticipated public opposition. This will require substantial effort in the Division of Traffic Operations, the Division of Maintenance and the Public Affairs Office.

Background:

1. Some highway signs were voluntarily converted to kilometers in the mid-1970's by State and Local Agencies in response to the 1975 Metric Conversion Act. There was much public debate as to the purpose and warrants for such a conversion, especially when gas pumps were converted to sell gasoline by the liter.
2. As a result of the public pressure, Congress passed legislation in 1978 prohibiting the use of Federal Funds for the installation of signs with metric messages.
3. The ISTEA rescinded the 1978 prohibition of Federal Funding for metric signing.
4. The FHWA Metric Conversion Plan established September 30, 1996 as the deadline to complete metric conversion for all FHWA functional areas and programs. The plan did not specifically discuss highway signing and therefore has been handled as a separate issue.
5. FHWA published "Options for Coordinating the Metric Conversion of Traffic Control Signs" in the August 31, 1993 Federal Register. Three options were presented: 1) Conversion Through Routine Maintenance; 2) Quick Conversion (over a six month period); and 3) Transition with Dual Units. Almost 3000 comments were received in response to the Notice. During the comment period, the 1994 Transportation Appropriations Act was passed by Congress containing a provision prohibiting the use of Federal-aid Funds for the placement of metric signs during FY 1994.
6. FHWA published the latest decision regarding highway signs in the June 27, 1994 Federal Register. Due to the comments received and the current fiscal year prohibition on funding, the FHWA has determined it is best to delay implementation of sign legend conversion until after 1996.

D. Conversion of Transportation & Encroachment Permits

Transportation Permits:

The transportation permit program primarily deals with truck size and weight allowances on the State Highway system. Primary consideration for conversion of these permits will be when the department and Local Governments change dimensions (such as vertical clearances) and posted weight restrictions on the highway system to metrics. These decisions will not be made until there is a nationwide signing policy established. These changes will also require close coordination with the California Highway Patrol and local law enforcement.

Encroachment Permits:

Districts will begin immediately advising permit applicants that Caltrans is converting to the metric system. Permit applicants will be advised that applications including project plans submitted after January 1, 1996 should be (but not mandated) in metric units. Applications submitted after July 1, 1998 must be in metric only units, unless there are extenuating circumstances that prohibit this. In those rare cases, the Districts can allow for dual units. Detailed instructions and suggested information to be sent to applicants will be provided to the Districts by the Division of Traffic Operations as soon as completed.

VIII. Tool and Equipment Needs

District and headquarters units were surveyed and metric tool and equipment items estimated at approximately \$1.5 million were established. These items consist of mainly expendable products such as metric tapes, reels, rules, rods, scales, thermometers, highway curves, grid sheets, etc.

The Caltrans, Office of Materiel Operations warehouse is in the process of purchasing approximately \$850,000 of the above items for warehouse stock. These will be purchased with 1994/95 Materiel Operations funds, and should be available early in the fiscal year.

Other items were identified which will not be carried in the Materiel Operations Warehouse. These consist mainly of non-expendable equipment such as testing machines, and incidental expendable equipment. Items not carried by the warehouse will need to be purchased by individual Districts or Divisions, and funded by their respective budgets, using established purchasing procedures.

Forms Management has notified all Divisions of the need to review their forms to determine whether or not changes need to be made to reflect metric requirements. These changes must be made prior to reordering forms.

IX. Implementation Schedule

ACTIONS TAKEN TO DATE

1. Alan Glen, Chief of the Geometric Design and Standards Branch in the Office of Project Planning and Design was appointed as the Department's Metric Coordinator in November 1992.
2. Departmental Director's Policy adopting the Metric system was approved on August 26, 1993.
3. Metric Policy Committee and Metric Steering Committee were formed in October 1993.
4. The Department began a communication program with issuance of newsletters in October 1993.
5. Metric Mapping and surveying standards were established in October 1993.
6. Caltrans Metric Primer was published in December 1993.
7. Technical Reports require dual units effective Jan. 1, 1994 and metric only Jan. 1, 1995.
8. Interim Design and Drafting Standards were issued on December 17, 1993.
9. A 4-hour Metric Training course was developed and instruction initiated in January 1994.
10. Initiation of Metric PS&E's on January 1, 1994.
11. Exceptions to Metric mandate were considered and approved by FHWA in April 1994.
12. Metric Conversion Plan approved by the Director in October 1994

IMPLEMENTATION SCHEDULE FOR REMAINING ACTIONS

1. Publish Revised Manuals, Standard Plans and Specification_____ July 1995
2. First Metric Projects delivered to HQ-Office Engineer_____ January 1996
3. First Metric Projects to be Advertised_____ Spring 1996
4. All advertised projects to be metric
(Except for projects with exceptions)_____ October 1, 1996

X. References

The following references are available as aids to metric conversion. A few of these references were used in the preparation of this Metric Conversion Plan.

METRIC CONSTRUCTION GUIDES

American Society for Testing and Materials (1916 Race Street, Philadelphia, PA 19103, Phone: (215) 299-5585):

- *ASTM E621, Standard Practice for the Use of Metric (SI) Units in Building Design and Construction*, 1984. 37 pp. 1984. \$12.00.

National Institute of Building Sciences (Publications Department, 1201 L Street N.W., Suite 400, Washington, DC 20005, Phone: (202) 289-7800):

- *The Metric Guide for Federal Construction*, 1st Edition, Operating Committee of the Interagency Council on Metric Policy, National Institute of Building Sciences (NIBS), Washington, DC, 1991. Written by NIBS specifically for the construction industry and reviewed by metric experts throughout the country. Includes background on the federal metric laws; facts on metrics in construction; an introduction to metric units; a primer on metric usage for architects, engineers, and the trades; requirements for metric drawings and specifications; guidance on metric management and training; and a list of current metric construction references. 34 pp. \$15.00 (including shipping and handling).
- *GSA Metric Design Guide*. Interim design guide developed by the General Services Administration (GSA) for use by federal project managers and their A/Es. Contains practical architectural, civil, structural, mechanical, and electrical design information; a list of available "hard" metric products; sample drawings; and related reference information. 77 pp. \$8.00; \$5.00 if ordered with the above *Metric Guide for Federal Construction*.

National Technical Information Service (5285 Port Royal Rd., Springfield, VA 22161, Phone: (703) 487-4600).

- NBS Technical Note 990, *The Selection of Preferred Metric Values for Design and Construction*. H.J. Milton, author. 75 pp.

GENERAL METRIC INFORMATION

American Association of State Highway Transportation Officials
(444 N. Capitol St., N.W., Suite 225, Washington, DC 20001; Phone
(202) 624-5800):

- *Guide to Metric Conversion*. May, 1993. \$10.00

American National Metric Council (Washington, DC; Phone:
(410) 727-0882 for publications):

- *ANMC Metric Editorial Guide*. \$5.00.
- *SI Metric Training Guide*. \$5.00.
- *Metrickation for the Manager*. \$15.00.

National Technical Information Service (5285 Port Royal Rd.,
Springfield, VA 22161; Phone: (703) 487-4600):

- PB 89-226922, *Metric Handbook for Federal Officials* (includes Federal Standard No. 376A of May 5, 1983, *Preferred Metric Units for General Use by the Federal Government*). 45 pp. 1989. \$17.00.

U.S. Government Printing Office- (Superintendent of Documents,
U.S. Government Printing Office, Washington, DC 20402; Phone: (202)
783-3238):

- NIST Special Publication 330, 1991 Edition, *The International System of Units (SI)*. 56 pp. August, 1991. \$3.50.
- NIST Special Publication 811, *Guide for the Use of the International System of Units*. Arthur O. McCoubrey, author. 34 pp. September, 1991. \$2.50.
- "Metric System of Measurement: Interpretation of the International System of Units for the United States"; Notice. *Federal Register*, December 20, 1990.

U.S. Metric Association (10245 Andasol Ave., Northridge, CA 91325;
Phone: (818) 363-5606):

- *Style Guide to the Use of the Metric System*. \$3.00; bulk discounts available.
- *SI Metric Style Guide for Written and Computer Usage*. \$2.00; bulk discounts available.
- *Freeman Training/Education Metric Materials List*. \$38.00.
- *Metric Vendor List*. \$28.00.

STANDARDS & SPECIFICATIONS

American Association of State and Highway Transportation Officials (444 N. Capitol St., N.W., Suite 225, Washington DC 20001; Phone (202) 624-5800):

- *Standard Specifications for Transportation Materials*. Two-volume set. Includes dual unit. \$115.00.

American Standards Institute, Inc. (11 West 42nd St., New York, NY 10036; Phone: (212) 642-4900):

- ANSI/IEEE 268, *American National Standard Metric Practice*. 48 pp. 1982. \$23.00.

American Society for Testing and Materials (1916 Race St., Philadelphia, PA 19103; Phone: (215) 299-5585):

- ASTM E380, *Standard Practice for Use of the International System of Units (SI)*. 35 pp. 1993. \$23.00.

CIVIL

American Congress on Surveying and Mapping (5411 Grosvenor Lane, Suite 100, Bethesda, MD 20814; Phone: (301) 493-0200):

- *Metric Practice Guide for Surveying and Mapping*. 11 pp. 1978. \$10.00.

American National Metric Council (1735 N. Lynn St., Suite 950, Arlington, VA 22209; Phone: (703) 524-2007):

- *ANNC Metric Editorial Guide*. Fourth edition. 16 pp. 1990. \$2.00
- *SI Metric Training Guide*. 17 pp. 1991.
- *Metric Guide for Educational Materials*. 22 pp. 1977.
- *Managing Metrication in Business and Industry*. 203 pp. 1976.

American Association of State and Highway Transportation Officials (444 N. Capitol St., N.W., Suite 249, Washington DC 20001; Phone: (202) 624-5800):

- *Interim Selected Metric Values for Geometric Design*. An addendum to *A Policy of Geometric Design of Highways and Streets, 1990*. 12 pp. 1993.
- *Traffic Engineering Metric Conversion Factors*. An addendum to the *Guide to Metric Conversion, 1993*. 3 pp. 1993.

STEEL

American Institute of Steel Construction (Metric Publication, One E. Wacker Dr., Suite 3100, Chicago, IL 60601-2001; Phone: (312) 670-5414):

- *Metric Properties of Structural Shapes with Dimensions According to ASTM A6M. Metric version of Part I of the Manual of Steel Construction.* \$10.00.
- *Manual of Steel Construction, Metric Edition.* To be published in 1994.

Industrial Fasteners Institute (1105 East Ohio Building, 1717 E. 9th St., Cleveland, OH 44114; Phone: (216) 241-1482):

- *Metric Fastener Standards.* \$60.00.

STRUCTURES

Florida Wire and Cable Company (P.O. Box 6835, Jacksonville, FL 32236; Phone: (800) 874-0093):

- *Physical Properties of Strand, Uncoated, Stress Relieved for Prestressed Concrete Structures.*

XI. Appendix:

A1-Policy Committee, Steering Committee, District and Division Metric Coordinators

Policy Committee:

Dick Weaver	Acting Chief Deputy Director	(916) 654-4438
Jim Roberts	Acting Deputy-Transportation Engineering	(916) 654-6490
Allan Hendrix	Deputy-Transportation Planning	(916) 654-5368
Lee Deter	Deputy-Transportation Management	(916) 654-6823
John Allison	District Director-District 3	(916) 741-4233
Harry Yahata	Deputy Director-District 4	(510) 286-5907
Peter Markle	Acting Division Administrator-FHWA	(916) 551-1282
Alan Glen	Caltrans Metric Coordinator	(916) 263-1042

Steering Committee:

Dick Bower	Legal Metric Coordinator	(916) 654-2630
Fred Carlson	Division of Highways Metric Coordinator	(916) 654-2978
Wayne Cornelius	Granite Construction Company (AGC)	(209) 855-4400
Jim Dicks	District 4 Metric Coordinator (Training Chair)	(510) 286-4999
Bob Everitt	Local Programs Metric Coordinator	(916) 653-7730
Larry Fenske	Division of Engineering Management	(916) 654-5491
Tom Finley	League of Ca. Cities-City of Sacramento	(916) 433-6382
Peter Fusselman	AGC of California	(916) 371-2422
Bob Galante	Office Engineer	(916) 654-4114
Al Gallardo	Alameda County Transportation Authority	(510) 893-3347
Bob Giess	Environmental Division Coordinator	(916) 263-1085
Chris Hatfield	Caltrans Division of Transportation Planning	(916) 445-6890
Bill Horden	CELSOC representative	(510) 419-6134
Dean Hiatt	District 11 Metric Coordinator	(619) 688-6461
Doug Jones	District 3 Metric Coordinator	(916) 741-4360
Rich Howell	Translab Metric Coordinator	(916) 227-7303
Jack Kletzman	Division of Traffic Operations	(916) 654-4715
Laura Luce	Division of Structures Metric Coordinator	(916) 227-8402
Dan Mundy	Mass Transportation Coordinator	(916) 654-6990
Ralph Nevis	Division of Administrative Services	(916) 445-6184
Lloyd Rue	Federal Highway Administration-Ca. Division Metric Coordinator	(916) 551-1305
Mohamed Shami	Division of Aeronautics Metric Liaison	(916) 323-4548
Bill Rinkleib	Division of Maintenance Metric Coordinator	(916) 654-3624
Dave Salmon	Division of Information Services	(916) 653-2727
Roland Swirsky	Right of Way Metric Coordinator	(916) 654-6437
Jack Warren	Placer County Department of Public Works	(916) 889-4000
Julie Horner	Division of Rail	(916) 227-9467

Division and District Metric Coordinators:

Statewide Metric Coordinator	Alan Glen	(916) 263-1042
District 1	Kathy Sartorius	(707) 445-5815
District 2	Burt Brockett	(916) 225-3570
District 3	Doug Jones	(916) 741-4360
District 4	Jim Dicks	(510) 286-4999
District 5	Jerry Gibbs	(805) 542-4606
District 6	Chuck Barsuglia	(209) 408-5953
District 7	Art Correa	(213) 897-0122
District 8	Heip Bui	(714) 383-4638
District 9	Dave Grah	(619) 872-0734
District 10	Shira Rajendra	(209) 948-7228
District 11	Dean Hiatt	(619) 688-6461
District 12	Bob Bazargan	(714) 724-2100
Division of Aeronautics	Mark Rayback	(916) 322-1227
Division of Construction	Kevin Chan	(916) 653-2032
Office Engineer	Robert Galante	(916) 654-4114
Division of Engineering Management	Larry Fenske	(916) 654-5491
Division of Maintenance	Bill Rinkleib	(916) 654-3624
Division of New Technology	Wes Lum	(916) 654-9776
Transportation Laboratory	Rich Howell	(916) 227-7303
Division of Right of Way	Roland Swirsky	(916) 654-6437
Division of State & Local Project Dev.	Bob Everitt	(916) 653-7730
Division of Structures	Laura Luce	(916) 227-8402
Division of Traffic Ops	Jack Kletzman	(916) 654-4715
Environmental Division	Bob Giess	(916) 263-1085
Division of Programming	David Brewer	(916) 654-4587

A2- Estimated Departmental Metric Conversion Cost

Organization	Operating Expense	PY's
Statewide Coordination	\$110,000	4.0
Division of Aeronautics	\$3,000	0.1
Construction/Office Engineer	\$701,000	23.0
Engineering Management (incl. Central Design)	\$135,000	18.0
Environmental Division	\$1,000	0.0
Highways	\$7,000	3.5
Information Services	\$1,000	7.0
Legal Division	0	0.2
Maintenance	\$103,000	3.5
Mass Transportation (Includes Rail)	\$1,000	0.2
New Technology	\$560,000	6.5
Project Development	\$252,000	6.0
Right of Way	\$93,000	7.5
Structures	\$359,000	52.0
Traffic	\$221,000	14.0
Transportation Planning	\$38,000	0.5
District 1	\$24,000	3.0
District 2	\$34,000	5.0
District 3	\$70,000	8.0
District 4	\$183,000	16.0
District 5	\$30,000	6.0
District 6	\$40,000	7.5
District 7	\$140,000	12.0
District 8	\$70,000	6.5
District 9	\$17,000	2.5
District 10	\$42,000	5.5
District 11	\$69,000	9.0
District 12	\$46,000	7.0
 SUBTOTAL FOR ALL DIVISIONS	 \$2,585,000	 146.0
SUBTOTAL FOR ALL DISTRICTS	\$765,000	88.0
 GRAND TOTAL	 \$3,350,000	 234.0
 20% Contingencies	 \$650,000	 46.0
GRAND TOTAL	\$4,000,000	280.0*

* These are not new PY's, they have been redirected from other workload.

A3-Metric Primer

The Metric Symbol



This is the Caltrans Metric Symbol. Its purpose is to make it clear immediately that a Caltrans document is using metric units. It should be placed in a prominent spot on all metric documents, including the following:

- Plans
- Project Reports
- Project Study Reports
- Project Approval Reports
- Drainage Reports
- Materials Reports
- Noise Barrier Scope Study Reports
- Structural Section Recommendation Reports
- Design Exceptions from Mandatory Standards
- Preliminary Reports
- Bridge Site Data
- Bridge Inspection Reports
- Geotechnical Reports
- Engineering Geology Reports
- Reports issued by the Transportation Laboratory
- Environmental Impact Reports
- Negative Declarations
- Categorical Exemption Reports
- Traffic Reports

This is not an exhaustive list. You should also use it in materials which pertain directly to the metric conversion or any other report or document in which units are expressed in the metric system.

Let's Get Metric

Welcome to the world of the metric system, or the International System of Units, often abbreviated as "SI". Caltrans has the privilege of leading California into this world.

Actually, the metric system has been around for more than two centuries. Benjamin Franklin and Thomas Jefferson first proposed that the US convert to the metric system, but it was more than two hundred years before another president, George Bush, in 1991, would sign an executive order to mandate that all agencies using federal money begin using the standard.

That's how we got into it. FHWA responded to President Bush's order by developing a plan requiring that all agencies using federal highway dollars begin advertising projects for construction using metric units by October 1, 1996. This booklet is a part of the Caltrans response to the federal mandate.

Actually, for a technical agency like Caltrans, metricating shouldn't be such a big deal. Most of our engineers were trained in the metric system in college. Our surveying equipment is already in metric and has to convert back to US units to make the data available. And most engineers prefer to work with orderly and systematic systems.

An international standard, called "ASTM E380", provides guidelines for the proper use of SI. Caltrans has adopted that standard, except that we use the American spelling of "liter" and "meter", rather than the French "litre" and "metre". This booklet, drawing on ASTM E380, contains basic information for your use in doing your job. That's why we call it a "primer". It contains basic descriptions of the units, conventions for writing the terms, and conventions for rounding and converting from the US system.

Your Basic Metric Stuff

The neatest thing about the Metric System is that all units are based on decimal mathematics. A kilometer is 1000 meters and a kilogram is 1000 grams (you'll understand later why there are no commas). No more eight pints to the gallon or 5,280 feet to the mile. No mils, inches, feet, yards, fathoms, rods, chains, furlongs, or miles. Here are some basics:

Meter (m): The basic measure of distance in the Metric System, a little longer than a yard.

Kilometer (km): The basic measure of longer distances, a little longer than a half-mile.

Millimeter (mm): For measuring the little stuff (a dime is about a millimeter thick). There's a centimeter too -- about a third of an inch -- but Caltrans probably won't measure in centimeters.

Liter (L): The Metric System's basic measure of liquid, a little larger than a quart.

Gram (g): For weighing the little stuff. A paper clip weighs about a gram.

Kilogram (kg): One thousand grams, weighing a little more than two pounds. The **tonne** or metric ton, about the weight of a fast sports car (1000 kilograms), is used for larger weights.

Time (s): The second, the basic measure of time, remains the same as in the US system.

Ampere (A): The basic measure of electric current, same as in the US system.

Candela (cd): The basic measure of luminosity.

Temperature (K): The basic measure of temperature. Celsius temperature ($^{\circ}\text{C}$) is used more commonly than kelvin (K), but both have the same temperature gradients. Celsius temperature is just 273.15 degrees warmer than kelvin, which begins at absolute zero. Water freezes at 273.15 K and at 0°C . To move between Celsius and kelvin, add or subtract 273.15.

The **radian (rad)** and **steradian (sr)** denote plane and solid angles. They are used in lighting work and in various engineering calculations. In surveying, the units **degree ($^{\circ}$)**, **minute ($'$)** and **second ($''$)** continue in use.

Terminology

Special Names

Measurable Attribute	Unit	Symbol	Expression
Frequency of periodic phenomena	hertz	Hz	$\text{Hz} = \text{s}^{-1}$
Force	newton	N	$\text{N} = \text{kg} \cdot \text{m}/\text{s}^2$
Energy/work/quantity of heat	joule	J	$\text{J} = \text{N} \cdot \text{m}$
Power, radiant flux	watt	W	$\text{W} = \text{J}/\text{s}$
Pressure/stress	pascal	Pa	$\text{Pa} = \text{N}/\text{m}^2$
Celsius temperature	degree Celsius	$^{\circ}\text{C}$	
Quantity of electricity	coulomb	C	$\text{C} = \text{A} \cdot \text{s}$
Electric potential	volt	V	$\text{V} = \text{W}/\text{A}$ or J/C
Electric resistance	ohm	Ω	$\Omega = \text{V}/\text{A}$
Luminous Flux	lumen	lm	$\text{lm} = \text{cd} \cdot \text{sr}$
Luminance	lux	lx	$\text{lx} = \text{lm}/\text{m}^2$

Derived Units

Measurable Attribute	Unit	Expression
Acceleration	meter per second squared	m/s^2
Area	square meter	m^2
Density/mass	kilogram per cubic meter	kg/m^3
Luminance	candela per square meter	cd/m^2
Pressure/Stress	newtons per square meter	N/m^2
Velocity	meter per second	m/s
Volume	cubic meter	m^3

Multiplication Factors

Multiple	Prefix	Symbol
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	*hecto	h
10 = 10^1	*deka	da
0.1 = 10^{-1}	*deci	d
0.01 = 10^{-2}	*centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n

* avoid where possible

Recommended Pronunciations

Prefix	Pronunciations
giga	jig' a (<i>i</i> as in <i>jig</i> , <i>a</i> as in <i>a-bout</i>)
mega	as in <i>mega</i> -phone
kilo	kill' oh
hecto	heck' toe
deka	deck' a (<i>a</i> as in <i>a-bout</i>)
deci	as in <i>deci</i> -mal
centi	as in <i>centi</i> -pede
milli	as in <i>mili</i> -tary
micro	as in <i>micro</i> -phone
nano	nan' oh (<i>an</i> as in <i>ant</i>)

Drafting Standards for Metric Plans

- Sheet sizes shall remain the same size until a nationwide paper change.
- Stationing shall be based on 100 meters per station.
- Scales

Plan Sheets:

Imperial Scale	Metric Scale	Grid Tick Interval
1" = 1'	1:10	
$\frac{3}{4}$ " = 1'	1:20	
$\frac{1}{2}$ " = 1'	1:20	
$\frac{3}{8}$ " = 1'	1:50	
$\frac{1}{4}$ " = 1'	1:50	
1" = 2'	1:20	
1" = 5'	1:50	
1" = 10'	1:100	
1" = 20'	1:200	50 m
1" = 40'	1:500	100 m
1" = 50'	1:500 (urban)	100 m
1" = 100'	1:1000 (rural)	200 m
1" = 200'	1:2000	500 m
1" = 400'	1:5000	1000 m

Crosshair legs shall be 20 mm long (actual plan dimension).

Profile Sheets:

- Rural sections in hilly or mountainous terrain - 1:100 vertical, 1:1000 horizontal
- Rural or urban with gentle rolling terrain - 1:50 vertical, 1:500 horizontal
- Rural or urban with level terrain - 1:20 vertical, 1:200 horizontal

Drafting Standards for Metric Plans, Continued

Cross Sections:

- Rural - 1:100
- Urban - 1:50
- Pavement cross slope and superelevation shall be shown as percent.
- Angular measurement shall retain Degree-Minute-Second convention.
- Cross section intervals shall be 20 m, or as required.
- Contour intervals:

Scale	Index Contours	Intermediate Contours
1:200	1 m	0.25 m
1:500	2 m	0.5 m
1:1000	5 m	1 m
1:2000	10 m	2 m
1:5000	25 m	5 m

- All survey information shall be expressed in meters. Output of survey information on Right of Way maps showing property data shall also be expressed in metric units.
- Dual units shall not be allowed on construction plans.
- Side slopes shall be expressed in nondimensional ratios. The vertical component is shown first and then the horizontal (Y:X). For slopes less than 45°, the vertical component shall be unitary (for example, 1:20). For slopes over 45°, the horizontal component shall be unitary (for example, 5:1) since the metric system does not use fractions.
- In general, dimensions smaller than 1 m should use millimeters. Dimensions greater than 1 m should be expressed as meters except if the English unit was traditionally shown in inches. If so, use millimeters. *Caltrans engineering work shall not use centimeters.*

Writing Conventions

- **Use upright text**

Correct: *Bob is running in tomorrow's 10 km race.*

Incorrect: *Bob is running in tomorrow's 10 km race.*

- **Plural same as singular**

Correct: To train for the **10 km** race, Bob runs 1 km a day.

Incorrect: To train for the **10 kms** race, Bob runs 1 km a day.

- **No period follows (except end of sentence)**

Correct: After the **10 km** race, Bob will walk 1 km.

Incorrect: After the **10 km.** race, Bob will walk 1 km.

- **Use lower-case (except for symbols derived from a proper name):**

Unit	Symbol:
centimeter	cm
millimeter	mm
kilometer	km
kilogram	kg
liter	L *
Celsius	°C
newton	N
joule	J

* The symbol "L" is recommended for liter in the United States, although both "L" and "l" are approved alternative symbols, since the letter l can easily be confused for the numeral 1. Written out, "Celsius", also an exception, uses capital "C".

- **Space Between Digit Number and Unit Symbol**

Correct: 35 mm
or 250 kg

Incorrect: 35mm
or 250kg

Exceptions: 45° and not 45 °
20°C and not 20° C

- **No Space Between Prefix or its Symbol and Unit**

Correct megapascal MPa
Incorrect mega pascal M Pa

Conventions (Continued)

- **With Symbols:**

Use Raised Dot for Product:

N·m for newton meter

- in WordPerfect [character "·" = CTRL-V (6,31)]

- in Microsoft Word, COMMAND+OPTION+Q, then
from symbol chart or ASCII 251

- with typewriter, use period (N.m)

raised dot

Use Slash or Solidus for Quotient:

example: meters per second: use m/s or m·s⁻¹ or $\frac{m}{s}$

- **With Unit Names**

Use Space or Hyphen for Product:

Correct: newton meter, or newton-meter

Incorrect: newtonmeter

Exception: watthour

Use "per" for Quotient (not /):

Correct: meter per second

Incorrect: meter/second

- **Group digits by three from decimal point. Use a "hard" space, *not* a comma** (refer to your software manual to avoid end-of-line separations) **to separate the digits.**

US	International (metric)
26,345	26 345
2.141596	2.141 596

In numbers with FOUR digits on either side of the decimal a space is not necessary except for uniformity in tables.

Correct: 0.1335 kg or 2345 kg

Incorrect: 0.133 5 kg or 2 345 kg

- **Fractions Unnecessary**

Correct: 2.5 m

Incorrect: 2 $\frac{1}{2}$ m

- **Use Zero before Decimal Marker**

Correct: 0.1234

Incorrect: .1234

Common Conversion Factors to Metric

Class	Multiply:	By:	To Get:
Area*	ft ²	0.0929	m ²
	yd ²	0.8361	m ²
	mi ²	2.590	km ²
Length*	ft	0.3048	m
	in	25.4	mm
	mi	1.6093	km
	yd	0.9144	m
Volume	ft ³	0.0283	m ³
	gal	3.785	L **
	fl oz	29.574	mL **
	yd ³	0.7646	m ³
	acre ft	1233.49	m ³
Mass	oz	28.35	g
	lb	0.4536	kg
	kip (1,000 lb)	0.4536	tonne (1000 kg)
	short ton (2,000 lb)	907.2	kg
	short ton	0.9072	tonne (1000 kg)
Density	lb/yd ³	0.5933	kg/m ³
	lb/ft ³	16.0185	kg/m ³
Pressure	psi	6894.8	Pa
	ksi	6.8948	MPa (N/mm ²)
	lbf/ft ²	47.88	Pa
Velocity	ft/s	0.3048	m/s
	mph	0.4470	m/s
	mph	1.6093	km/h
Light	footcandle		lux (lx)
	(or) lumen/ft ²	10.764	(or) lumen/m ²
Temperature	°F	$t_{°C} = (t_{°F} - 32) / 1.8$	°C

* For land surveying, see "Land Surveying Conversion Factors" table on page 10, below

** Use Capital "L" for liter to eliminate confusion with the numeral "1"

Land Surveying Conversion Factors

Class	Multiply :	By:	To Get
Area	acre	4046.87261	m ²
	acre	0.404 69	ha (10 000 m ²)
Length	ft	1200/3937*	m

* Exact, by definition of the US Survey foot, Section 8810, State of California Public Resources Code

Less Common Conversion Factors

Class	Multiply:	By:	To Get:
Density: Gravity Force	lbf/ft ³	157.0	N/m ³
	lbf/in ³	271.0	kN/m ³
	kgf/m ³	9.81	N/m ³
Density: Mass	lb _m /in ³	27.68	Mg/m ³
	lb _m /gal (US)	119.8	kg/m ³
Force (including gravity force)	dyne	0.01	mN
	kgf	9.81	N
	oz _f	0.278	N
	lbf	4.45	N
Mass	ton _f (2000 lb _f)	8.90	kN
	carat (metric)	0.2	g
	oz _m (avoirdupois)	28.35	g
	oz _m (troy)	31.10	g
	lb _m	0.454	kg
	slug	14.6	kg
	ton _m (short)	0.907	Mg

Note: The Metric System eliminates the confusion in US terminology about "weight" by separating it into two definitions: "mass", and "gravity force". Mass refers to the inertia of an object, or the force required to accelerate or decelerate it in a gravity-free environment. Gravity force is the net downward force acting on a stationary object to attract it to another, always proportional to the strength of the gravitational field and the object's mass.

Conversion And Rounding

General:

- Conversion from US to SI may be either exact ("soft"), or a suitable approximation ("hard").
- In a **soft** conversion, the US unit is converted to an **exact** metric equivalent.
- In a **hard** conversion, the US unit is converted to a **new rounded, rationalized metric number** convenient to work with.
- In all conversions, use SI equivalents similar in magnitude to the original. If a 1/16 inch scale was suitable for the original measurement, a 1 mm metric scale is suitable for the conversion.

Conversions

- Always establish intended precision as a guide to how many digits to retain after conversion. The number 1.1875 may be a very accurate decimalization of a number that could have been expressed as 1.19. The value 2 may mean "about 2," or it may be a very accurate value of 2, expressed as "2.0000".
- The converted dimension should be rounded to a minimum number of significant digits so the unit of the last place is equal to or smaller than its conversion.

Example:

Precision of a 6 inch stirring rod is estimated at about $\frac{1}{2}$ in ($\pm \frac{1}{4}$ in) or, converted, 12.7 mm. The converted dimension, 152.4 mm, should be rounded to the nearest 10 mm and shown as 150 mm.

- Converted values should be rounded to the minimum number of significant digits in order to maintain the required accuracy.

Example:

A length of 125 ft converts exactly to 38.1 m. But if the 125 ft length was obtained by rounding to the nearest 5 ft, the conversion should be given as 38 m; if it had been obtained by rounding to the nearest 25 ft, the result should be rounded to 40 m.

Conversion and Rounding, continued

- A stated limit such as "not more than" must be handled so the limit is not violated. "At least 3 inches wide" requires a width of at least 76.2 mm, or at least 77 mm.
- When converting, multiply a value by a more accurate factor than required, then round appropriately afterward. Rounding before multiplying will reduce accuracy.

Example:

When converting 3 feet 2 $\frac{9}{16}$ inches to meters ($\frac{9}{16}$ " = 0.5625"):
 $(3 \times 0.3048) + (2.5625 \times 0.0254) = 0.979\ 487\ 5$ m, rounds to 0.979 m

Significant Digits

- When converting integral values of units, consider the implied or required precision of the integral value to be converted.

Example:

The value "4 in." may represent 4, 4.0, 4.00, 4.000 or 4.0000 in.

- Any digit necessary to define the specific value or quantity is significant.

Example:

Measured to the nearest 1 m, a recorded distance of 157 m would have three significant digits. Measured to the nearest 0.1 m, a distance of 157.4 m would have four significant digits.

- Zeros may indicate either a specific value or an order of magnitude. As an example, the population of the United States in 1970, rounded to thousands, was 203 185 000. The six left-hand digits are significant, each measuring a value. The three right hand zeros indicate that the number has been rounded to the nearest thousand.
- Identifying significant digits is only possible by knowing the circumstances by which they were originally arrived at. For example, if the number 1000 is rounded from 965, only one zero is significant. If it is rounded from 999.7, all three zeros are significant.

Conversion And Rounding, continued

- When adding or subtracting, the answer must contain no significant digits to the right of the least precise number.

Example:

For the problem:

Round the numbers one significant digit to the right of the least precise number and take the sum as follows:

163 000 000	163 000 000
217 885 000	217 900 000
96 432 768	96 400 000
<hr/> 477 317 768	<hr/> 477 300 000

(Round the total to 477 000 000 as called for by the rule)

- When multiplying or dividing, the product or quotient must contain no more significant digits than the fewest significant digits used in the multiplication or division.

Example:

$113.2 \times 1.43 = 161.876$ -- round to 162 because 1.43 has three significant digits

$113.2 \div 1.43 = 79.1608$ -- round to 79.2 for same reason.

Rounding Values

- When the first digit discarded is less than 5, the last digit retained is not changed.

Example:

3.463 25, rounded to four digits would be 3.463; if rounded to three digits, 3.46.

- When the first digit discarded is greater than 5 or is a 5 followed by at least one digit other than 0, add 1 to the last digit retained.

Example:

8.376 52, rounded to four digits would be 8.377; if rounded to three digits 8.38.

- When the first digit discarded is exactly 5 followed only by zeros, the last digit retained should be rounded upward if it is odd. No adjustment is made if it is an even number.

Example:

4.365, rounded to three digits becomes 4.36. The number 4.355 would round to the same value, 4.36, if rounded to three digits.

A4-Communications Plan

Overall Strategy

- **Positive Attitude Toward Metrication:** Conversion to metrics means that Caltrans will continue to maintain its place as a worldwide leader in transportation engineering.
- **Ease of Use:** Metrication provides important benefits for the Caltrans technical staff with regard to engineering and other technical processes. Studies by the US Metric Council have shown that metric calculations are as much as 40% faster than in US units.
- **Overcoming Resistance:** Some individuals may feel that the metric system is a "foreign", or "un-American" intrusion. This should be countered by a theme that American involvement in development of the SI system has been extensive ever since it was first proposed, and that all countries have had to make this transition, not just the US.

Organization

- The Communications Subcommittee directs the communications effort as outlined above.
- All communication with the media is handled by Caltrans Offices of Public Affairs, either in headquarters or districts.
- The chief spokesperson for the conversion is Chief Engineer Jim Roberts. The Metric Coordinator does the primary job of communicating about the metrication program.
- Communication with the State Legislature and other political entities is handled by the Caltrans Office of Legislative Affairs in the Director's Office.
- Communication with other agencies is handled through the Metric Steering Committee and its technical subcommittees, the Caltrans Office of Local Programs, the League of California Cities, and the California State Association of Counties.
- Communication with relevant industry contacts is handled through their representatives, CELSOC and AGC, APWA, and other industry organizations.
- Communication with FHWA is handled by the Metric Coordinator, the Steering Committee and FHWA's metric coordinator.

Audiences

- Caltrans Staff
 - Engineering Staff
 - Others

- Other Agencies

Other State Agencies

Local Agencies

Federal Agencies

- Public

Suppliers

Contractors

Consultants

Political bodies

Permittee

Recipients of Caltrans reports and printed materials

Other business

General Public

- Materials distributed externally requiring conversion

State Transportation Improvement Program

Route Concept Reports

Systems Management Reports

Initial Project Scope Reports

Draft Project Reports

Project Study Reports

Project Fact Sheets

Project Development Team displays and handouts

Project Status Reports

Cooperative Agreements

Freeway Agreements

Initial Project Reports

Right of Way Data Sheets

Right of Way property descriptions

Right of Way Data Sheets

Right of Way Relocation Impact Statements

Right of Way booklets

Traffic Forecasts

Traffic Management Plans

Environmental Impact Statements

Written Notices of Studies

Noise/air/visual/energy/flood plain/wetlands/biological studies

Materials Reports, Geotechnical Reports and Foundation Studies

Negative Declarations

Hazardous Waste Site Assessments

Notices for Public Hearings

Brochures for public hearings

Hearing displays/handouts/maps

Maps and Displays

Value Engineering Reports

High Occupancy Vehicle Reports

News releases

Permit applications

Construction bulletins

Media advisories
Advertisements
Correspondence
Contact Sheets

Communication Techniques

- **Caltrans Staff**

Kickoff Announcement by Chief Engineer in the form of Deputy Directive
Kickoff Story by Chief Engineer in Going Places Magazine
Policy and Steering Committees communicate up and down the line through normal chain-of-command.
Manuals and other materials as appropriate
Interim design standards and policies communicated through information bulletins
Development of a metric symbol to be used as an identifier on all metric materials
Development of a simple booklet providing a basic tool for metric calculations and conversions
Poster Program
Newsletter (effective September 1994, the newsletter is canceled and replaced with Departmental memorandums as needed)
Quick conversion card
Placement of materials in other Caltrans newsletters such as district and headquarters newsletters, etc.
Communication through E-Mail.

Other Agencies

Steering Committee and technical advisory committees
Briefings to advisory committees
Newsletter
California Transportation Symposium May 11-13, 1994
Team Building Meetings
Local Programs Newsletter
CTAP Newsletter

Public

Caltrans will not begin conversion of road signs until a nationwide effort is initiated; thus no general public information campaign has been addressed at this time. When such a conversion is initiated, it is assumed that the general informational campaign would be coordinated through the federal agency responsible for the conversion.

A brochure will be produced to provide some basic information about reasons for the conversion and the metric system to members of the public who are confronted with reports or documents containing metric units.

Caltrans Public Affairs Officers should be thoroughly briefed on the conversion, and all materials made available to them so they can handle inquiries from members of the public.

A5-Training Plan

Objectives

The Metric Training Program provides Caltrans staff members with adequate skills to perform tasks using metric measurements. The course does not seek to provide a full understanding of all metric terminology. Its purpose is rather to provide enough familiarity with the metric system and metric conversion processes so that staff members can avail themselves of the tools necessary to perform their jobs.

At the conclusion of the course, students will:

1. Use the seven basic units of the metric system
2. Use rules and conventions for reading and writing in metric
3. Understand the difference between hard and soft conversions
4. Be familiar with the Caltrans metric primer
5. Use metric scales, converters and calculators
6. Complete conversions from US to metric with at least three different kinds of units

Target Population(s)

The target population for the Metric Training Program is all Caltrans staff who are required to do their jobs using metric measurements. While it is probable that all staff will eventually have to become conversant with metric units, the training plan assumes the following will have an early need for training:

Classifications	Numbers to be Trained
A. Transportation Engineers	5,000
B. Land Surveyors	700
C. Right of Way Agents	400
D. Landscape Architects	200
E. Environmental Planners	200
F. Transportation Planners	200
G. Maintenance Staff	200
H. Administrative Staff	200
I. Other	500
Total	7,600

Course Administration

Training is most effective when provided in an intensity which matches job requirements and administered right before the start of use of the metric system. The training is most effective when provided in the work place.

The Metric Steering Committee has identified photogrammetry, surveys, conversion of mapping and appropriate computer software and technical report writing as the earliest metrication activities which must proceed. Therefore, the first training courses should be administered to individuals in these disciplines. Steering committee members from those disciplines will be asked to provide a schedule for those needing the instruction by December 1, 1993. The department

has directed that all technical reports will be expressed in metric units after January 1, 1994, and plans for projects to be advertised for bids after January 1996 will also begin conversion on that date. Training for selected individuals involved in any of these activities should therefore begin in December 1993 or as early thereafter as possible.

The Metric Training Committee has developed a four-hour course incorporating videotapes and other materials from Workplace Training. Each training session provides training to about 30 staff. Providing training to the target population will thus require approximately 200 classes. Roughly, these are distributed as follows, based on district size:

District	Classes	Trainees
01	8	240
02	8	240
03	15	450
04	35	1,050
05	9	270
06	11	330
07	40	1,200
08	9	270
09	5	150
10	10	300
11	15	450
12	12	360
HQ	25	750
Total	200	6,000

Because it is impossible for a single trainer to handle a task of this magnitude the training course is being administered by district and headquarters staff. A training for trainers course, providing familiarity with the course content and elementary training skills has been completed and administered.

While the general concepts of metrication being taught are consistent, the course is adaptable so as to be presented on two levels, one for technically-oriented staff who have the mathematical skills to do conversions, and a second for those who will have to develop those basic skills. Technically oriented staff is given an opportunity to work on more complex problems and to become familiar with metric standards and specifications which they are likely to use in their jobs.

It is unlikely that all staff members will have to be given the four-hour course. Maintenance and clerical staff, for instance, are getting a shorter version which is appropriate only for their uses.

Local Agency Availability

Caltrans has purchased the rights to reproduce copyrighted materials used in the training module and has made them available through CTAP and ITS to the local agencies to administer for their own purposes. This half-day workshop is available through ITS Extension for on-site presentation at a cost of \$300 for a maximum of 40 people. ITS Extension can be reached at (510) 231-9590.

Availability to Consultants and the Transportation Construction Industry

Caltrans has not obtained rights to use copyrighted materials for private industry. However, Caltrans has a particular interest in seeing to it that the transportation construction industry is conversant with the metric system. Caltrans is working with representatives of the transportation construction industry on this.

Course Content and Instruction Methodology

Hour 1 - Basic Concepts of Metrics

1. Short discussion of the background of the metrication effort (Tutor)
2. Familiarize students with Metric Primer
3. Familiarize students with course notebook.
4. Introduce videotape of basic units of the metric system.
5. Videotape of basic units of the metric system.
6. Post-test and discussion.

Hour 2 - Methods of Reading and Writing in Metric

1. Pre-test reading and writing in metric
2. Short introduction to videotape describing methods of reading and writing in metric. (Tutor)
3. Videotape describing methods of reading and writing in metric.
4. Post-test, feedback and discussion

Hour 3 - Conversion I

1. Introduction to metric converters and calculators.
2. Short introduction to videotape about conversion to metric. (Tutor)
3. Videotape on conversion to metric.
4. Exercises in conversion.

Hour 4 - Conversion II

1. Discussion by tutor
2. Exercises in advanced conversion.
3. Final exam, feedback and discussion

Training Materials

Metric Primer
Videotapes 2, 3 and 6
Metric Scales
Metric Converter and Calculator
Class Workbook



A-6 Implementation Schedule Bar Chart

